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A quantitative investigation of learning styles, motivation and learning strategies for undergraduate engineering students

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ABSTRACT: Students' learning styles, motivation and learning strategies have been receiving increasing attention in the international engineering education community in recent years, and there is a need to design the most appropriate curriculum and pedagogy to best meet the diverse needs of students. The present study focuses on a quantitative investigation of learning styles, motivation and learning strategies among a representative group of undergraduate engineering students at Universiti Teknologi Malaysia. Statistical analysis based on student responses to the index of learning styles (ILS) survey and to the motivated strategies for learning questionnaire (MSLQ) survey was performed. The results show that the surveyed students have a balanced preference for all learning style dimensions, except for visual learning, and that they have better motivation than learning strategies. The research findings imply that when designing curriculum and pedagogy, instructors should pay attention to providing students with visual aids, as well as step-by-step guidance for problem-solving, and should also emphasise teaching students how to learn.

Keywords: Learning styles, motivation, learning strategies, undergraduate engineering students

INTRODUCTION

Student learning is affected by many factors including the students' background and experience, the effort they devote to learning, their cognitive abilities, their meta-cognitive skills (such as motivation and self-efficacy), the quality of curriculum and instruction, the effectiveness of institutions' student-supporting systems, and so on [1-5]. Teaching and learning methods in engineering education have changed in the last few years in line with the advancement of new technologies. Instructors should anticipate students' learning preferences, so that students can be assisted to learn the complex nature of engineering knowledge. The role of instructors nowadays is not only to teach new knowledge, but also to guide students in how to learn, explore and apply new information in new ways [6].

Engineering education instructors should also recognise that the students in his or her classroom differ from one another in a variety of ways including learning styles, motivation and learning strategies. These three factors are receiving increasing attention from the international engineering education community, and there is a need to design and develop the most appropriate curriculum and pedagogy to best meet these diverse needs. Thus, it is not surprising that a significant amount of research has shown that these three factors play an important role in affecting student learning outcomes.

Learning Styles

Learners with diverse backgrounds and experiences have different ways of learning that they prefer. For example, when learning new knowledge and skills, some learners prefer to see pictures and diagrams, whilst other learners prefer to listen to instructors' verbal explanations. Most learners have multiple preferences. The different preferences are called learning styles. In past decades, a wide variety of theories or models regarding learning styles have been developed [7-11]. For instance, Kolb developed an experiential learning model based on four categories of learning styles, including diverging (concrete and reflective), assimilating (abstract and reflective), converging (abstract and active), and accommodating (concrete and active) [7]. Extensive research evidence has shown that optimal learning outcomes would be achieved when a learner's learning styles and an instructor's teaching styles match with each other [7-11].

According to Felder …*it is important not to determine each student's learning style and then teach to it exclusively, but to teach around the learning cycle* [12]. This calls for educators to have a balanced approach from both sides of the same dimension. Since understanding and addressing students' learning style in the classroom will lead engineering students to develop an appreciation of engineering knowledge, educators should consider learners' learning styles when designing curriculum and instruction.

Motivation

Motivation involves the variety of reasons why learners want to learn. It is often the driving force behind learners' behaviour. Research has shown that motivation plays a significant role in achieving maximum learning outcomes [13-17]. A learner with high motivation would more likely spend more time and effort on learning tasks than a learner with low motivation. Seifit reported five patterns of learners' behaviours that are directly associated with motivation, including mastery, failure avoidance, learned helplessness, work avoidance, and passiveness-aggressiveness or hostile work avoidance [13].

Factors affecting learners' motivation have also been studied. For example, based on an achievement goal framework, Meece et al examined the effects of classroom and school environments on students' academic motivation and achievement [14]. They found that classroom environments not only affect students' academic engagement and achievement, but also students' motivation and self-perceptions. In addition, researchers have also shown that instructors' engagement with students during class time is linked to increasing students' intrinsic motivation to learn. Other studies have also identified that engineering students' motivation to learn are closely related to their persistence, achievement and interests [18].

Learning Strategies

Learning strategies include both cognitive and meta-cognitive strategies (such as thoughts and actions) that learners use when learning new knowledge and skills [19-22]. A substantial amount of research evidence has demonstrated a strong co-relationship between learning strategies and academic achievement. For example, based on a path analysis of 283 high school students in geometry classes, Pokay et al found that when students were first exposed to the new course content early in a semester, their use of subject-matter-specific strategies and effort and persistence were related to academic achievement [19]. When students were more familiar with the course content later in the semester, learning strategies that involved planning and monitoring progress became more predictive of students' grades.

The Objective and Structure of the Present Study

The objective of the present study is to determine learning styles, motivation and learning strategies of a representative group of undergraduate engineering students at Universiti Teknologi Malaysia in Malaysia. First, two survey instruments that were employed in this research are described, including the index of learning styles (ILS) survey [23] and the motivated strategies for learning questionnaire (MSLQ) survey [24]. Both survey instruments have a high degree of reliability and validity. Next, the method of data collection is introduced. Then, major results from statistical analysis are presented and discussed, followed by a discussion of the limitations of the present study. Finally, conclusions are made at the end of this article.

INDEX OF LEARNING STYLES (ILS) SURVEY

The index of learning styles (ILS) survey [23] is a 44-item, self-scoring instrument that that assesses learning style preferences on four pairs of dimensions of the Felder-Silverman model [8]. This questionnaire survey was developed particularly for engineering students. The four pairs of dimensions are: active/reflective, sensing/intuitive, visual/verbal and sequential/global. The definition of these dimensions can be found from the original work by Felder and Silverman [8]. Students respond to each of the 44 items in the questionnaire survey. For example, in Item 1 the statement to be confirmed is …*I understand something better after I (a) try it out; (b) think it through?* Students' submissions are, then, automatically scored on the Internet for each pair of dimensions of learning style preferences [23].

MOTIVATED STRATEGIES FOR LEARNING QUESTIONNAIRE (MSLQ) SURVEY

The motivated strategies for learning questionnaire (MSLQ) is a well-adopted, self-reported instrument assessing college students' motivational orientations and their use of different learning strategies in a college course [24]. It measures students' intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, test anxiety, rehearsal, elaboration, and so on. This 81-item instrument is divided into the motivation scale (31 items) and the learning strategies scale (19 items). Each scale has a set of sub-scales. The definitions of each scale can be found in the original work by Pintrich et al [24].

DATA COLLECTION

A total of 42 first-year undergraduate students in the Faculty of Mechanical Engineering at Universiti Teknologi Malaysia responded to the two surveys. Students' responses to the index of learning styles (ILS) survey were automatically scored over the Internet [23]. The score ranges were from 1 to 11 points, where 1-3 points represents a balanced preference between the two dimensions in the same pair; 5-7 points a moderate preference for one dimension over the other dimension in the same pair; and 9-11 points a strong preference for one dimension over the other dimension in the same pair. As an example, Figure 1 shows a student's scores in each pair of learning style dimensions. Based on Figure 1, this student has a balanced preference between active and reflective; between sensing and intuitive; and between sequential and global learning style dimensions. The student has a very strong preference for visual learning over verbal learning.

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ACT                                  X                           REF
     11   9   7   5   3   1   1   3   5   7   9   11
                          <-- -->

SEN                              X                               INT
     11   9   7   5   3   1   1   3   5   7   9   11
                          <-- -->

VIS  X                                                           VRB
     11   9   7   5   3   1   1   3   5   7   9   11
                          <-- -->

SEQ                          X                                   GLO
     11   9   7   5   3   1   1   3   5   7   9   11
                          <-- -->
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Figure 1: Example: a student's scores in each pair of learning style dimensions.

Qualtrics, a popular computer software package designed for surveys, was employed to create 81 on-line survey items included in the motivated strategies for learning questionnaire (MSLQ) survey [24]. Students were asked to respond to these 81 on-line items on the Internet. For each item, students chose a scale between 1 and 7 points, where 1 means *not at all true of me* and 7 means *very true of me*. SPSS, a popular computer software package designed for statistical analysis, was employed to analyse students' responses to these survey items.

RESULTS AND ANALYSIS

Learning Styles

Table 1 shows the results of a statistical analysis of students' learning styles. As can be seen from Table 1, overall, students' preferences for all learning style dimensions were balanced, except for visual learning (moderate preference). As many as 81.8% of the surveyed students prefer visual learning, as compared to only 18.2% of the students preferring verbal learning. In addition, as many as 72.7% of the surveyed students prefer sequential learning, as compared to only 27.3% of the students preferring global learning.

Table 1: Statistical analysis of students' learning styles.

Learning styles	Active	Reflective	Sensing	Intuitive	Visual	Verbal	Sequential	Global
Percentage of students	54.5%	45.5%	45.5%	54.5%	81.8%	18.2%	72.7%	27.3%
Mean	3.00	3.80	3.20	2.75	7.33	2.50	4.00	3.00
Standard deviation	2.26	2.70	2.57	2.26	3.31	1.91	2.42	2.19
Average preference	Balanced	Balanced	Balanced	Balanced	Moderate	Balanced	Balanced	Balanced

The above results imply that when designing curriculum and pedagogy, instructors should pay more attention to providing students with visual aids. As the majority of students are visual learners, visual aids, such as figures, graphs, pictures, hands-on demonstration, and computer simulation and animation, are particularly helpful for students to understand the concepts and problems students are studying. For example, many important concepts in engineering mechanics, such as general planar motion of a rigid body, are abstract concepts that many students have difficulty understanding via the instructor's verbal explanations. Hands-on demonstrations or computer simulations and animation can help students visualise how a rigid body moves in a 3D space and how the velocity and acceleration of the rigid body vary as the position of the rigid body changes. In the well-known study of *How People Learn* [25], it is also recommended that a variety of visual aids be used in instruction to maximise student learning outcomes.

The above results also imply that when designing curriculum and pedagogy, instructors should pay attention to a detailed explanation of step-by-step procedures for problem-solving. As the majority of students are sequential learners, step-by-step explanations of how to solve a problem help students master problem-solving procedures. For examples, when solving an engineering mechanics problem that involves the use of Newton's Second Law, several steps should be followed. Step 1: construct a free-body diagram and a kinetic diagram. Step 2: Apply Newton's Second Law to set up kinetics equations in x- and/or y-directions. Step 3: Compare the number of unknowns and the number of available equations. Find additional equations if the number of unknowns is more than the number of available equations.

Motivation

Table 2 shows the results of a statistical analysis of students' motivation. Note that the data shown in Table 2 is based on a 7-point scale with 1 for *not at all true of me* and 7 for *very true of me*. Based on the mean values (4.52 - 5.33) listed in Table 2, students have moderate motivation. The lowest score is for test anxiety (4.52), and the highest score is for the control of learning belief (5.33).

Table 2: Statistical analysis of students' motivation.

Sub-scale (number of survey items)	Mean	Standard deviation
Intrinsic goal orientation (4)	5.03	0.18
Extrinsic goal orientation (4)	5.27	0.35
Task value (6)	5.29	0.12
Control of learning beliefs (4)	5.33	0.35
Self-efficacy for learning and performance (8)	5.06	1.15
Test anxiety (5)	4.52	0.71

As stated, the scales in the motivated strategies for learning questionnaire (MSLQ) survey [24] are based on a 7-point scale where 1 means *not at all true of me* and 7 means *very true of me*. In general, a higher score of 4-7 is better than a lower score of 1-3, with the test anxiety scale as the only exception. A high score in test anxiety means more worrying of a student about his/her test performance [24]. The results in Table 2 indicate that in general, the surveyed students were motivated for learning, but worried about tests.

The above results imply that stress-reduction activities should be included in the design of extra-curricular activities beyond student learning in the classroom. For example, educational professionals and psychologists should be invited to hold seminars and workshops on how to reduce stress and cope with test anxiety. The tips offered in these seminars and workshops would better prepare students for tests and increase student performance in tests.

Learning Strategies

Table 3 shows the results of statistical analysis of students' learning strategies, based on the same 7-point scale. From Table 3, the mean scores are close for all sub-scales and vary within a small range from 4.50 to 4.74.

Table 3: Statistical analysis of students' learning strategies

Sub-scale (number of survey items)	Mean	Standard deviation
Rehearsal (4)	4.68	0.35
Elaboration (6)	4.74	2.00
Organisation (4)	4.50	0.18
Critical thinking (5)	4.67	1.84
Meta-cognitive self-regulation (12)	4.66	0.71
Time/study management (8)	4.58	1.15
Effort regulation (4)	4.59	1.06
Peer learning (3)	4.53	2.36

From Table 2 and Table 3, the average score is 5.1 for the motivation scale (including six sub-scales) and 4.6 for the learning strategies scale (including eight sub-scales). Therefore, it can be concluded that on average, the surveyed students have higher motivation than learning strategies. This research finding implies that when designing curriculum and pedagogy, instructors should place more emphasis on teaching students a set of useful learning strategies; that is, how to learn. A comprehensive review of the literature shows that many studies have been conducted on how students learn [25], with few studies on how students *should* learn. Students have a variety of learning strategies; however, not every learning strategy is effective. Research studies on how students should learn is an important topic for engineering education.

From Table 2 and Table 3, it can also be found that students varied significantly in six sub-scales according to the values of standard deviations. In Table 2 and Table 3, the six sub-scales in which standard deviation is more than one include: self-efficacy for learning and performance (1.15), elaboration (2.00), critical thinking (1.84), time/study management (1.15), effort regulation (1.06) and peer learning (2.36). The standard deviation in two of these six sub-scales was even more than two: peer learning (2.36) and elaboration (2.00). These results demonstrate that students are significantly different in terms of peer learning and elaboration. Peer learning is also termed as cooperative learning and collaborative learning, in which students learn from each other in teams or groups. Elaboration not only requires students to have a solid understanding of a problem, but also to have excellent communication skills. As the world becomes flat and many engineering projects involve international collaborative efforts, peer learning and elaboration play an increasingly important role in contemporary engineering education [1]. Therefore, in designing curriculum and pedagogy, educators should create opportunities to improve students' peer learning and elaboration skills.

LIMITATION OF THE PRESENT STUDY

The present study has two primary limitations. First, the number of participants (n = 42) involved is limited. The research would be enhanced if the sample size was increased. Second, the scope of the present study is limited in determining students' learning styles, motivation and learning strategies. A further study that co-relates the three factors to academic achievement would provide a better understanding on how these factors affect student learning.

CONCLUSIONS

Overall, the surveyed students have balanced preferences for all learning style dimensions, except for visual learning (moderate preference). The research findings imply that instructors should pay attention to providing students with visual aids, as well as a detailed explanation of step-by-step procedures for problem-solving. Among the surveyed students, the average score was 5.1 for the motivation scale and 4.6 for learning strategies. The surveyed students have higher motivation than learning strategies. The research findings imply that instructors should also place emphasis on teaching students how to learn.

The analysis of the results has shown that for this group of engineering students, they have balanced preferences for all the learning style except for visual learning. Results indicate that most of the engineering students prefer to learn through visual means. The finding is similar to the results reported by other researchers. Therefore, for engineering students, instructors are encouraged to include visual-based instructional strategies to enhance students' learning. Instructors of engineering courses should give greater emphasis to preparing their teaching materials based on visual learning styles.

The results from the present study indicate that most of the students have a preference for more than one learning style. Instructors should be encouraged to prepare their instructional learning materials based on a balanced approach that is suitable for both sides of each of the four dimensions, to account for more than one of the learning style preferences. Using a balanced approach would also be suitable for students who are more likely to have a balanced preference learning style described earlier. Furthermore, from the findings of the study, instructors should guide students on how to learn subject matter in relation to the context of specific engineering discipline. Further research should examine how the construct of engineering students' learning strategies are related to their motivation to learn.

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